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The apple leaf-hopper

R. L. Webster
Iowa State College

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EXPERIMENT STATION

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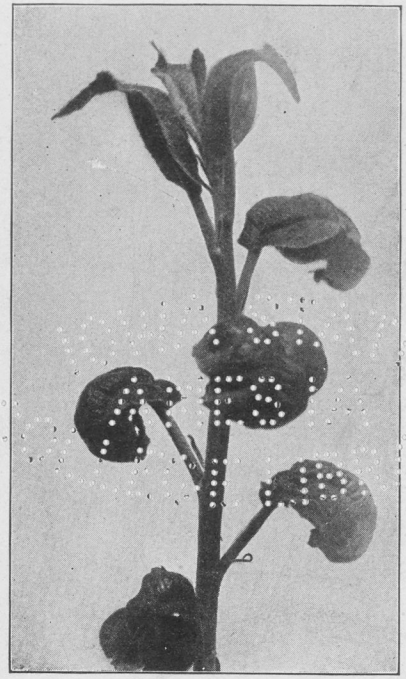

ENTOMOLOGY SECTION

THE APPLE LEAF-HOPPER

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SUMMARY OF BULLETIN NO. 111.

1. The apple leaf-hopper is a tiny, active greenish insect which injures nursery stock, especially apple trees, by curling up the tender leaves and thereby stunting the growth. This kind of injury is shown on the front page of this bulletin. Occasionally this insect causes serious damage to potato plants.

2. The leaf-hoppers are very small in their younger stages, and even the old insects are only about an eighth of an inch long. The old hoppers have wings, and are very active, sometimes flying up in clouds from badly infested trees when they are disturbed.

3. Some of the leaf-hoppers spend the winter in the adult stage, under dead leaves or in similar places. Others winter over in the egg stage, in the bark of apple trees.

4. In Iowa the young hoppers are especially common on nursery stock four times during the season; in the latter part of May, June, July, and August, when the different generations appear. The curling of the leaves does not appear until June.

5. Like the plant-lice, the leaf-hoppers do not have biting mouth-parts, but simply suck the sap from the leaves. For that reason they cannot be controlled with Paris green or any of the arsenical poisons.

6. Spraying infested stock does not seem to be practicable, since the curled leaves make it so difficult to hit the insects which are on the under sides. Trapping the hoppers on sticky shields is only partly successful. This should be done when the old hoppers are most common, and when there are favorable wind conditions.

7. Experiments during 1909 showed that the dipping of nursery stock in simple soap solutions was effective in killing practically all of the leaf-hoppers on the trees dipped. For southern Iowa the best time for this dipping is about the 20th of June and July; for central Iowa, the 25th, and for northern Iowa, the 30th. The June treatment is the more important one. Trees might also be treated about the same time in August. These dates are figured so that the dipping would be done at times when the young hoppers are most common, and when it would be most effective.

8. Solutions of whale oil soap and white laundry soap were found to be very successful as dips. The first was used 1 pound to 8 gallons of water, and the second 1 bar (about 10 ounces) to 8 gallons.

9. To be effective this dipping must be thoroughly done, and well timed, so as to catch the insects when they are most susceptible.

THE APPLE LEAF-HOPPER.

Empoasca mali LeB.

By R. L. Webster.

INTRODUCTION

RECENT INJURY IN IOWA NURSERIES.

The retardation of growth of apple stock in Iowa nurseries, caused by the apple leaf-hopper, has been very common from year to year, and has resulted occasionally in extensive losses to young nursery stock. The large nurseries at Charles City, Des Moines, and Shenandoah, as well as many others in the state, are more or less troubled with this insect every year. Although this leaf-hopper attacks many kinds of plants and trees, the injury is most serious on young apple trees, especially when planted in the nursery row, and it is as a nursery pest that this insect is considered in this bulletin. During the past year the apple leaf-hopper was more abundant than common, and as a result a large amount of nursery stock was stunted seriously. Aside from apple trees this insect frequently attacks birch and Norway maple trees, and even potatoes. The pest is known to science as *Empoasca mali.*

GENERAL APPEARANCE OF THE INJURY.

The work of the apple leaf-hopper first becomes evident to the nurseryman by a peculiar curling of the growing tops of nursery stock, particularly of the apple stock, during the month of June. At this time the older stock probably will be most affected, although later in the season the younger stock is likely to suffer. This curling of the young terminal leaves is periodical in its appearance during the growing season. A period of curled leaves is followed by a short period during which the leaves are not curled, and so on throughout the season. Figure 2 shows an instance where a shoot has been curled by the hoppers, and has outgrown the injury. The terminal leaves are uncurled while the leaves below are curled. In cases of severe injury the terminal leaves may be badly curled all through the season.

The result of an attack of the leaf-hoppers is that the growth of the new wood is shortened, the leaves grow close together on the branches, and the whole tree fails to attain the size it should in a season's growth. Consequently many nursery trees do not become the proper size in three years and frequently they must be left for another year to complete their growth.

SPECIFIC INDICATIONS OF THE PRESENCE OF THE LEAF-HOPPERS.

Since the leaf-hopper feeds on the under sides of the leaves, they are curled under, sometimes rolled under from the end of the leaf. The apex of the affected leaf is curled under the rest of the leaf, until the whole is broadly rolled under in such a manner as is shown in figures 1, 2, and 3. These insects do not feed upon the particles of the leaf, but simply suck the juices from it by means of their short beaks. No holes are eaten through, but where the leaf-hopper has been at work the upper surface of the leaf appears spotted with very small brown areas, where the plant juices have been removed by the insect. This injury is shown in figure 4.

The curling of the leaves is very similar to that caused by aphids, or plant-lice. The leaves are not so tightly curled, however, and in the case of aphis injury the soft-bodied plant-lice are usually found on the leaves and stem. The leaf-hoppers are more active, and move quickly when disturbed.

During periods when the curling is most conspicuous the tiny, pale greenish leaf-hoppers may be seen on the under sides of the curled leaves. When disturbed, the young hoppers move over the leaf quickly in a sideways fashion, but the winged adult insects, and indeed some of the older nymphs without wings, are able to hop some little distance out of the way. Anyone walking through rows of nursery stock when the adult hoppers are numerous will notice at once the insects rising in a body from the young trees.

THE INSECT'S APPEARANCE.

The apple leaf-hopper, in its adult stage, is a small, pale green insect, about an eighth of an inch long. The adult hoppers are provided with wings, but the younger ones, or nymphs as they are called, are without wings. The winged

adult leaf-hopper is shown in figure 11, while the wingless nymphs are shown in figure 10, all being much enlarged.

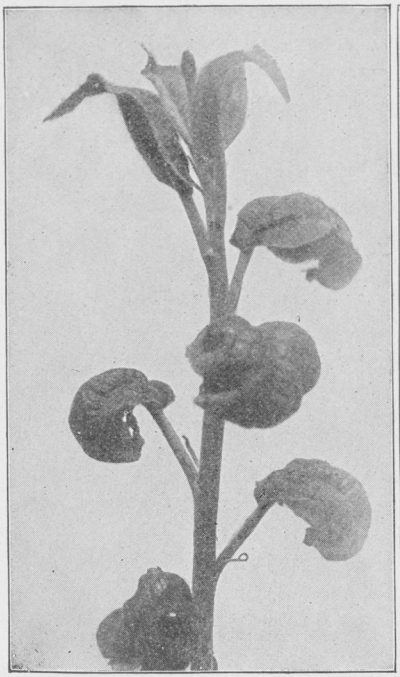

FIG. 1. CURLED LEAVES CAUSED BY APPLE LEAF-HOPPER

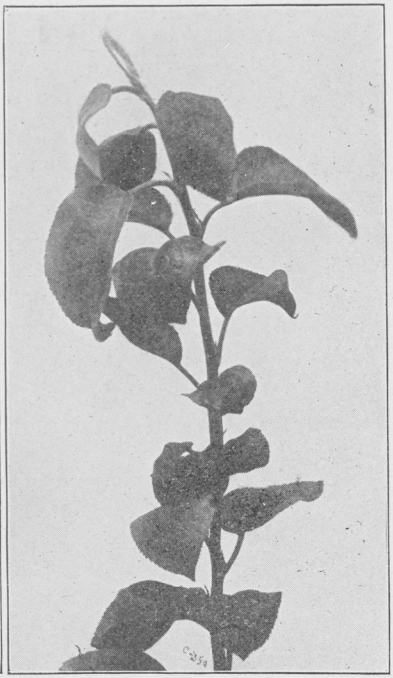

FIG. 2. LEAF-HOPPER INJURY OUTGROWN BY TERMINAL LEAVES

TIME OF APPEARANCE OF THE DIFFERENT GENERATIONS.

The leaf-hoppers spend the winter in two different ways, Some of the old winged hoppers place their eggs in the bark of apple trees in the fall; others live on through the winter, hiding away under dead leaves, or under some other protection. The eggs in the bark of the apple trees hatch soon after the buds burst in the spring, and about the same time the old hoppers come out from their hiding places. Although the hoppers are present on the apple trees long before June, the curling of the leaves does not become evident until toward the latter part of that month.

The first generation of young hoppers, hatching from the eggs in May, feeds mostly on older leaves, which do not curl up when attacked as the fresh unfolding terminal leaves

do. The second, third and fourth generations of young hoppers, which are found on the trees in the latter part of June, July, and August respectively, each curl the terminal leaves. It is important to know just when the young nymphs are most abundant, so as to apply remedies when they will kill the greatest number of insects. In September the hoppers gradually disappear as they become mature, some of the mature forms depositing their eggs in apple bark, others living through the winter to appear the following spring.

CONTROL MEASURES

Undoubtedly the apple leaf-hopper is the worst insect pest with which the Iowa nurseryman has to contend. The large range of food plants, and the fact that there are several generations during the season, make it a most difficult insect to control. Both liquid and dust sprays have been advised

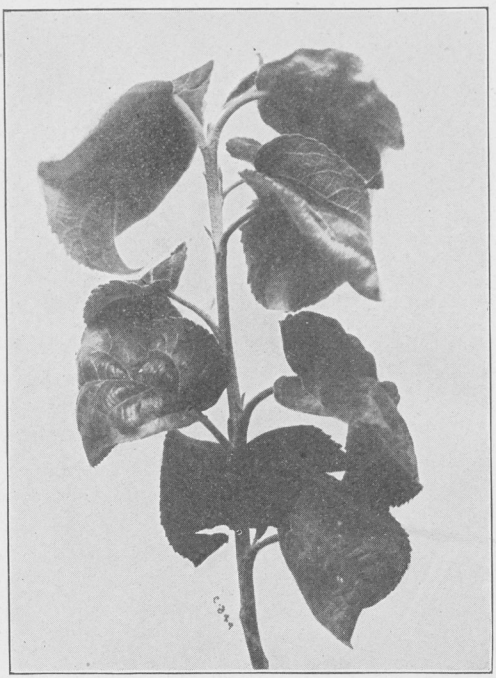

FIG. 3. LEAF-HOPPER INJURY TO HIBERNAL LEAVES.

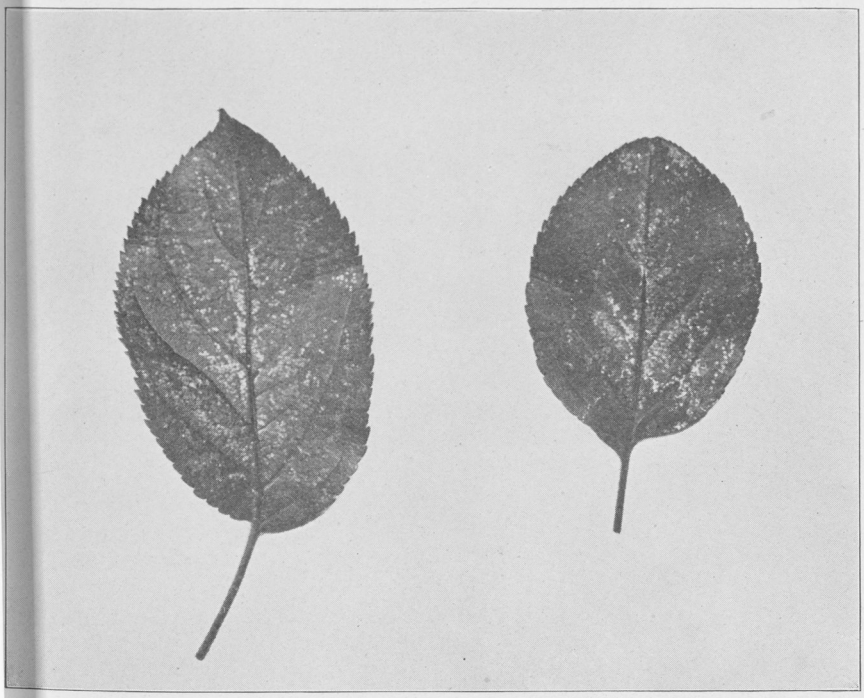

FIG. 4. LEAF-HOPPER WORK ON UNCURLED LEAVES.

for it, but in either case the curled leaves make it so difficult to hit the insects that spraying is hardly profitable. Trapping on sticky shields will catch many of the old hoppers, but this method is not successful unless the wind conditions are very favorable. The dipping of nursery stock seems to be about the most satisfactory method by which this insect may be kept in check, although even this is open to objection on account of the large amount of labor it requires. The leaf-hoppers may be killed easily if this dipping is done while they are young and more susceptible to treatment. With a proper solution it is an easy matter to kill practically all of the hoppers on the trees dipped.

During the summer of 1909 a number of experiments were made in order to determine what control measures would be most effective in Iowa nurseries. A general account of these experiments, together with brief notes concerning experimental work in other states, is given in the following pages.

DIPPING NURSERY STOCK.

The fact that nursery stock might be dipped in some insecticide mixture to kill the leaf-hoppers was first brought to my notice by the experience of Mr. S. D. Sayers, of the E. L. Watrous nursery at Des Moines. Mr. Sayers first used a mixture of whale oil soap and other materials for aphids on nursery stock, and he found that this preparation killed the leaf-hoppers also. Accordingly when the apple stock was attacked by the hoppers the trees were dipped and the insects killed in large numbers.

The mixture used was made according to the following formula:

4 pounds whale oil soap
3 bars white laundry soap
1 bushel tobacco stems
1-2 gallon kerosene
50 gallons water.

The soap was dissolved by boiling it in a quantity of water in a vat, and the tobacco stems were steeped in a second vat. The kerosene was poured into the soap while it was still boiling and the concentrated solutions were dipped from the vats and diluted to the required 50 gallons. The mixture was taken to the field in a barrel loaded on a float.

The dipping was done by a gang of men who went down the rows with pails of the mixture, thrusting the tops of the young trees directly into the pails. These men worked across rows forty rods long in an hour, dipping every tree. From observations made by the writer it appeared that this dipping was effective where thoroughly done. It seemed probable, however, that a more simple solution could be used, and have the same effectiveness, and further experiments were planned along that line.

WHALE OIL SOAP.

Through the kindness of Capt. C. L. Watrous of Des Moines, solutions of whale oil soap and white laundry soap were tested on the grounds of the Capital City nurseries. Apple stock was dipped August 24 in solutions of whale oil

soap at the following different strengths: 1 pound of soap to 6 gallons of water, 1-8 and 1-10. Both the 1-6 and 1-8 solutions killed practically all of the hoppers that were touched. The 1-10 solution was too weak for effective use, since many of the leaf-hoppers were not killed by it. No injurious effects to the leaves were noticed when these rows were examined August 31. From the above experiments it is evident that a simple solution of whale oil soap diluted at the rate of 1 pound to 8 gallons of water will kill practically all of the hoppers it touches.

WHITE LAUNDRY SOAP.

In the same nursery apple stock infested with the hoppers was dipped with solutions of white laundry soap, August 25. The soap was dissolved by boiling and diluted to the proportions 1-6, 1-8, and 1-10. In this case the proportions refer to bars of soap and not to pounds. The bars weigh about 9 3-4 ounces.

The mixtures 1-6 and 1-8 were both very effective, but the 1-10 solution left about 10 per cent of the hoppers alive. From these results 1 bar of white laundry soap to 8 gallons of water appears to be the weakest strength at which this soap may be used consistent with good results. There was no injury apparent to the foliage August 31.

IVORY SOAP.

Trials of both Ivory soap and Lenox soap were made on the grounds of the Sherman Nursery, at Charles City, through the kindness of Mr. E. M. Sherman. The Ivory soap was dissolved by boiling and diluted to several different proportions: 1 bar (large size) to 2 gallons of water, 1-4, 1-6, 1-8, 1-12, 1-15, and 1-18. The large laundry size bar of Ivory soap is the 10 cent size, and weighs 8 to 9 ounces. These trials were made July 26 and 27, 1909.

It was found with more diluted solutions of Ivory soap that some of the leaf-hoppers would recover, although they appeared to be dead soon after the dipping. For this reason observations were made both immediately after the dipping, and several hours later, as well as on the following day. The various strengths up to and including the 1-8 strength killed

practically all of the hoppers touched, but on the rows treated with the weaker solutions many young hoppers recovered.

In a row of Whitney No. 20 trees treated with 1-2 solution some injury was noted to the growing tips several days after the treatment. This strength, however, was much more concentrated than was needed for the work. The 1-8 mixture appears to be the best proportion in which Ivory soap may be used.

LENOX SOAP.

This soap was used in but two proportions: 1 bar to 2 gallons of water, and 1-3. The bars weigh about 12 ounces. Both of these solutions seemed fairly effective, but the soap turned many young tender leaves yellowish, so that its use seems impracticable on this account. The 1-2 strength killed about 98 per cent of the hoppers.

SPRAYING.

It was found soon after this insect became well known, that when the hoppers could be hit, there was little difficulty in killing them. But the trouble lay in hitting the insects. Both liquid and dust sprays were used, with more or less satisfaction. A short account of some of this previous experimental work follows:

Doctor Weed in 1889 said that pyrethrum and tobacco dust were effective against the immature stages. Where the leaves were not badly curled a dust spray probably would be effective, if applied when the nymphal stages were most common.

Much experimental work has been done with liquid sprays. Here again difficulty is found in hitting the hoppers. Prof. C. P. Gillette first made the statement that kerosene emulsion would kill the hoppers. Prof. Osborn used the same insecticide with success for the insect on potatoes. Prof. F. L. Washburn had partial success with a kero-water outfit, and also with kerosene emulsion. In 1907 a number of spraying experiments were made by the writer in southern Minnesota nurseries.* Spraying with kerosene emulsion for the first generation of leaf-hoppers, which work on the lower leaves

*Washburn, F. L. Minn. Agr. Exp. Sta. Bul. 112, 1908, p. 156.

of the nursery trees, was fairly effective. The spraying for the second generation was not so effective, on account of the badly curled terminal leaves at that time. Other materials were also used, but with similar results.

A few young apple trees at Ames were sprayed August 20 with whale oil soap, 1 pound in 10 gallons of water. The application was made with a small compressed air sprayer, and the nozzle was pushed close up under the growing tips where the young hoppers were feeding. Where the nymphs were hit squarely they were killed, but on account of the curling this was impossible in most cases. The spraying was a decided failure.

TRAPPING.

Sticky shields have been used to some extent in New York state against grape leaf-hoppers. These shields are merely light wooden frames covered with cloth, which is smeared with some sticky substance. The shields are carried down the rows, and the insects caught on them. In 1907 a shield of this sort was given a trial at the Clinton Falls nursery, Owatonna, Minnesota, by the writer. An account of this trial is given herewith, taken from a bulletin of the Minnesota Experiment station, and the notes of the writer.*

"A light frame was made, 3 by 4 feet, with a handle, and covered with heavy cloth. The cloth was then covered with O. & W. Thum's Tree Tanglefoot, a one-pound jar making a heavy coating to within two inches of the frame. This grade of tanglefoot is rather stiff in consistency, and a thinner grade could have been used and more surface covered. One man held the frame by the handles, walking down one side of the row of trees, while the other jarred the trees from the other side. A gentle breeze was blowing at nearly right angles with the rows, and the shield was used on the side away from the wind. The hoppers left the trees in swarms when jarred, and flew with the wind and downward, the greater part of them being caught by the tanglefoot on the sticky shield. On account of the fact that the hoppers flew downward, more were caught on the lower side of the frame than the upper. Two men, in working for ten minutes, covered 290 feet in a row of 5 year old apple stock, and an actual count of the num-

*Washburn, F. L. Minn. Agr. Exp. Sta. Bul. 112, 1908, p. 158

ber of leaf-hoppers on the frame caught in 10 minutes work was 3221, on a surface of 3 by 4 feet. About 95 per cent of these were adults."

On July 27, 1909, a similar frame smeared with a resin-castor oil mixture was tried at the Sherman nursery at Charles City, Iowa. This home-made mixture was composed of 1 pound of resin and 1 pint of castor oil. The resin was first melted and the castor oil then added. The mixture was taken off the fire a few minutes later. It was rather sticky, though not so much so as the prepared "tanglefoot". The frame was made of light 1 by 2 inch timber and measured 6 feet long by 2 feet 10 inches wide. At the top were two handles, placed towards the middle of the shield. Two legs were placed at the bottom, one at each corner, lifting the shield about 4 inches from the ground. Heavy cloth was tacked over the frame.

This frame, smeared with the resin-castor oil mixture, was taken to rows of European birch badly attacked by the hoppers. The wind was gentle and struck the rows diagonally. A good number of hoppers were caught, but not enough to call it a success. Had the wind been directly across the rows doubtless the result would have been different. The shields should be used at times when the old hoppers are most abundant, that is, about the second week in June, July and August, the earlier the better. In the Charles City experiment the adults seemed to be quite numerous on the birch trees, although on the apple trees the younger stages were most abundant.

Hopperdozers have been used to a small extent by Prof. Washburn in Minnesota against this insect. These are box-like frames built so as to be drawn along over rows, catching the hoppers inside of the inclosure, which is smeared with tar or some other substance. Washburn has referred to a similar apparatus used in Missouri nurseries by Prof. J. M. Stedman.

It has been suggested that the hoppers might be attracted to light and caught in lantern traps. Observations made at Ames show that this attraction is not great enough so that it could be used in this way.

STEPS ADVISED.

The selection of a treatment for nursery stock against the apple leaf-hopper is a difficult problem. Any of the measures that are known will allow some proportion of the insects to escape, depending upon the treatment itself, the care with which it is made, the time the work is done, as well as upon other factors. So far as the leaf-hoppers that are actually on a tree at a given time are concerned, dipping would kill practically all of them. If the dipping is done when the hoppers are hatching out rapidly, however, one may go over the dipped rows the next day and find young nymphs that have hatched out over night.

In some cases it may be unnecessary to treat trees. Certain varieties such as Northwestern Greening, Iowa Beauty and some others, which are never seriously injured, would not be much benefited by dipping. However, on varieties which are more affected, and where it is desired to have a strong growth, undoubtedly the dipping would keep the hoppers down so that the trees would be benefited greatly. The older trees might be left untreated, since they are less likely to be injured seriously.

Of the soap solutions, either the whale oil soap or the white laundry soap are equally effective, and since they are low in cost, they are regarded as best for use. The whale oil soap may be bought for 3 to 6 cents a pound, depending upon the quantity purchased. The white laundry soap sells at the rate of 6 or 7 bars for 25 cents.

Reference to the table of generations (Fig. 6) will show the times during the summer when the young hoppers are most abundant; in the latter part of June, July, and August. The generation coming on the trees in June is the one which it would be best to attack, since this one starts the curling of the leaves and the consequent checking of growth.

For southern Iowa the 20th of June or July would be the correct time for dipping, since at these times the young nymphs are most numerous. For central and northern Iowa, the proper dates would be about the 25th and the 30th respectively, of the same months. These dates are figured from observations and counts in different parts of the state, and should be accurate enough so that the treatment may be well timed. The dates should allow most of the eggs to hatch before the dipping. These same dates might be used during

August, but dipping should by no means be delayed until that time.

PAST HISTORY, DESTRUCTIVENESS AND DISTRIBUTION.

The apple leaf-hopper probably has been more or less numerous in Iowa ever since apple trees were planted in this state. Since it appears to be a native insect, it probably was present here even before that time. In 1891 Prof. C. P. Gillette mentioned this insect as being injurious to apple stock in Iowa nurseries.* Prof. Herbert Osborn in 1896 also recorded the abundance of this leaf-hopper at Ames upon potatoes.**

The apple leaf-hopper caused considerable injury to apple trees in Illinois as far back as 1853, when it was first described by Doctor LeBaron. In 1884 Doctor Forbes mentioned its destructiveness to young apple trees in the same state. Several nurseries in southern Minnesota have suffered considerable injury in the past few years by attacks of this insect and Prof. F. L. Washburn, State Entomologist of Minnesota, has made the leaf-hopper the subject of much investigation. Prof. P. J. Parrott records serious injuries to potatoes and beans in New York state, Mr. N. E. Shaw notes injuries in Ohio, and Prof. H. Garman in Kentucky. The most injury, however, has occurred in the states of the Mississippi valley.

The injury caused by the apple leaf-hopper is that the growth of the trees is checked. Older trees may withstand the attack fairly well, but the younger stock is not always able to do so. Mr. E. M. Sherman, of the Sherman Nursery Company at Charles City, tells me of an attack on a block of young Whitney No. 20 and Patten's Greening trees, in which the trees were most seriously injured.

Forty or fifty leaf-hoppers have been counted commonly on single 3 year-old apple trees. On one 4-year-old apple tree as many as 124 leaf-hoppers have been found. At this rate it is no great wonder that nursery trees suffer as they do.

That the apple leaf-hopper is present to some extent in every nursery in the state is not to be doubted. Since it is a native insect, its mere presence need be no cause for alarm, on account of the general distribution over the country.

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*Gillette, C. P. Trans. Iowa State Hort. Soc. for 1890 (1891) p. 104.
**Osborn, Herbert. Iowa Agr. Exp. Sta. Bul. 33, 1896, p. 594.

From the literature, it seems that the species has a wide distribution in North America. It has been collected from Quebec and Ontario (Metcalfe) to the District of Columbia, (Pergande, Heideman), Kentucky (Garman), Mississippi (H. E. Weed), Missouri, and Nebraska, as well as in many of the states between. Prof. Geo. G. Ainslie, of Clemson College, South Carolina, writes me that he has found the species common in that state. In the collection of Jassidae at Iowa State College is a single specimen bearing the label "Albuq. N. M." (Albuquerque, New Mexico). Besides this there are several specimens collected at Orizaba and Motzorongo, Vera Cruz, Mexico, by Prof. Herbert Osborn, in 1892.

Doctor Berg described his *Typhlocyba photophila* from Corrientes, Argentine, so that, assuming that this is a synonym of *Empoasca mali*, that species has a very wide range of distribution.

FOOD PLANTS.

Prof. C. P. Gillette in 1898 gave a list of the food plants then observed*. These were as follows: Apple (Le Baron). currant, gooseberry, corn, (Forbes), beans, potatoes, wild grapes, plum (Davis), *Populus monilifera* (Van Duzee). Davis also recorded celery as a food plant.** In 1900 Forbes and Hart*** added other food plants to the list as follows: Sugar beet, clover, sorghum, black walnut, *Ptelea trifoliata*, elm, oats, rye, grass "and some weeds". Washburn† in 1908 recorded many others in addition: European birch, cut leaf birch, maple, box-elder, quack grass, buckwheat, dahlia, hazel, choke-cherry, sumac, bur oak, thorn-apple, black oak, blackberry, syringa, snowball, carranga, *Physocarpus opulifolius*, raspberry, rhubarb, hemp, and alfalfa. Gibson†† records the species from basswood (Metcalfe); Shaw‡ notes it on hollyhock.

In addition to this list the insect has been found by the writer on the following plants: Grape, cherry, rose, Norway maple, mountain ash, horse chestnut, ash, poplar, and compass cherry. Mr. Henry Ness has found it on pear and Rhamnus. Doubtless the list could be added to indefinitely, since few of the plants examined were without leaf-hoppers.

*Gillette, C. P. Proc. U. S. Nat. Mus. Vol. xx. p. 745.
**Davis, C. G.-Mich. Agr. Exp. Sta. Bul. 102. p. 28.
***Forbes, S. A. and Hart, C. A.-Ill. Agr. Exp. Sta. Bul. 60, p. 426.
†Washburn, F. L.-Minn. Agr. Exp. Sta. Bul. 112. p. 155.
††Gibson, Arthur-37th. Rep. Ent. Soc. Ont. p. 79.
‡Shaw, N. E.-Ohio Dept. Agr. Div. Nurs. & Orch. Insp. Rep. Insp. 1908. p. 17.

Several varieties of apple stock are less affected than others. The Northwestern Greening, Iowa Blush, Walbridge, Malinda, Iowa Beauty, and Yellow Transparent, seem to be the less injured in Iowa nurseries.

CLASSIFICATION.

SYNONYMY.

The original description of the apple leaf-hopper by Doctor LeBaron* was published in the Prairie Farmer in 1853, together with an account of the injury. It was here called *Tettigonia mali.*

In 1879 *Typhlocyba photophila* was described by Doctor Carlos Berg** from Argentine, but this is considered by Prof. C. P. Gillette*** as a probable synonym of *Empoasca mali* LeB. In 1884 this leaf-hopper was again described by Doctor S. A. Forbes,† State Entomologist of Illinois, who considered it to be a new species and gave it the name of *Empoa albopicta.*

The synonymy may be expressed as given herewith.

Empoasca mali LeBaron. 1853.
photophila Berg. 1879.
albopicta Forbes. 1884.

COMMON NAME.

Since the injuries caused by this insect probably are most marked on apple stock in nurseries, this food plant certainly would have the right to be coupled with the term "leaf-hopper" in order to form its common name. Doctor Forbes has called it the "green apple leaf-hopper", while Doctor Weed, referring to this species on currants and gooseberries, has termed it the "currant leaf-hopper". It has also been called "the thrips" by nurserymen, but since this term should properly be restricted to another very different group of insects, that name for the insect in question is both incorrect and misleading. The name "apple leaf-hopper" has been adopted for use by the American Association of Economic Entomologists, and since it seems to be the most fit name, it is used herein.

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*LeBaron, Wm.-Prairie Farmer, Sept. 1853. p. 330.
**Berg, Carlos-Hemiptera Argentina. 1879. p. 273.
***Gillette, C. P.-Proc. U. S. Nat. Mus. Vol. xx. 1898. p. 744.
†Forbes. S. A.-13th. Rep. State Ent. Ill. 1884, p. 181.

LIFE HISTORY

GENERAL ACCOUNT.

The apple leaf-hopper spends the winter in Iowa both in the egg and in the adult stages. The adults and newly hatched nymphs appear soon after the leaves are out, and they may be found on nursery stock early in the spring. So far as it is known the eggs which winter over are deposited only in the bark of apple trees. During the summer the eggs are deposited on a large variety of plants.

There are five nymphal stages of the insect and it requires only about a month to complete the life cycle from egg to adult. In Iowa there are four generations, counting the generation which hatches from the egg early in the spring as the first. The leaf-hoppers are found on foliage as late as the middle of October, although the most of them are gone by that time.

Coincident with the appearance of the young hoppers in large numbers on nursery trees the terminal leaves of the attacked stock become curled. This curling appears in the latter part of June, July and August. The foliage is not curled by those nymphs which hatch from eggs early in the spring, since they feed on the older leaves on the lower part of the nursery trees.

In the spring of 1909 the young leaf-hoppers seemed to hatch at practically the same time in different latitudes of the state. The first nymphs for the year were found in a well exposed block of apple trees at Shenandoah, May 13. On May 19 at Ames the young hoppers were found in practically the same condition as at Shenandoah. On arriving at Charles City, May 21, the writer was surprised to find first and second stage nymphs on apple leaves. It was expected that the eggs would be unhatched, but from indications they had begun to hatch several days before. At Shenandoah when the leaf-hopper nymphs were first found the apple trees were nearly in full bloom, but at Charles City, May 21, the blossoms were just beginning to appear. The difference in latitude between Charles City and Shenandoah amounts to about 160 miles. In 1907 in Minnesota the first nymphs were found May 25, at Albert Lea, in the southern part of the state.

NUMBER OF GENERATIONS.

Forbes and Hart* have suggested that there are four or more generations during the season in Central Illinois. Professor Washburn** supposed that there were two and "almost certainly three" generations in Minnesota. The writer has made the statement that there were probably five generations in this state, but more complete observations show that this supposition was unwarranted.

During the latter part of the summer of 1908 and in the season of 1909 counts of the leaf-hoppers were made at regular intervals in a block of apple stock at Ames. One hundred or more leaf-hoppers, nymphs and adults, were counted each time, and classified as "young" or "old" insects. Those nymphs of stages I, II, and III were termed "young" and the nymphs of stages IV, V, and the adults were called "old". In this way the stages were grouped evenly so that the scarcity or abundance of either group would become evident when the data was plotted. In the tables the figures used indicate the percentage of young nymphs of stages I, II, and III.

Figure 5 shows the preliminary count made in 1908. This merely shows the gradual disappearance of the young hoppers from the leaves. These first counts were made weekly.

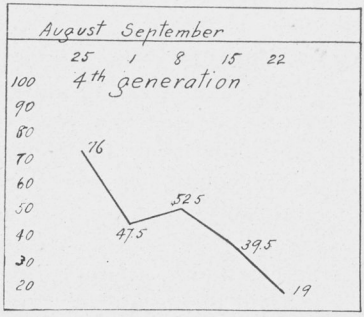

FIG. 5. COUNTS OF YOUNG NYMPHS, 1908.

In 1909 the counts were made twice a week, beginning with the second generation in June. Up to this time the generations were distinct. According to notes the first nymphs of the second generation appeared on these trees

*Forbes, S. A. and Hart, C. A.-Ill. Agr. Exp. Sta. Bul. 60, p. 427.
**Washburn, F. L.-Minn. Agr. Exp. Sta. Bul. 112. p. 153.

June 15. The counts were made by Mr. Henry Ness and the writer and are tabulated in figure 6.

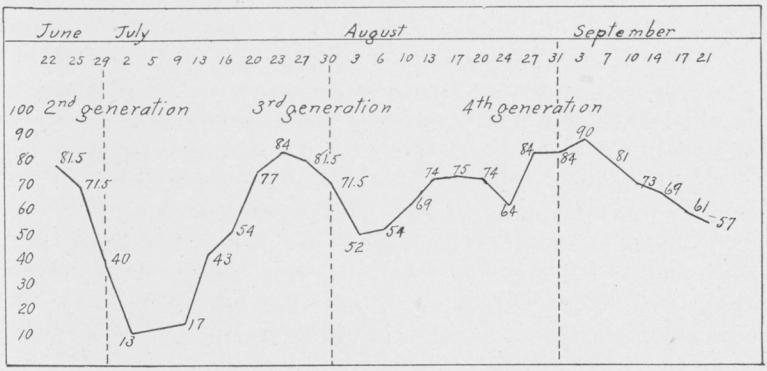

FIGURE 6. COUNTS OF YOUNG NYMPHS. 1908.

From this figure the second, third, and fourth generations are rather clearly outlined. As might be expected, the records during the latter part of the season are not sharply contrasted, and the last generation is spread over a longer time than the others.

What the writer has called the first generation is not a full generation, compared to those succeeding it. This first generation comprises only the hoppers hatching from the eggs which have wintered over. The second generation, however, is composed of the progeny of the adults of this first generation, and also of the adults which have hibernated.

On July 22-24, 1909 comparative counts of leaf-hoppers were made at three places in the state, representing the northern, central and southern portions. These counts were taken in nurseries at Charles City, Des Moines, and Shenandoah, to determine the relative advancement of the developing genration at those places. One count was made on Northwestern trees and a second count on trees of mixed varieties. The figures given are percentages of young nymphs found in the counts of large numbers of all the leaf-hoppers found on the trees. Considerable difference was found in the counts, which are given below. A second count at Charles City is added for comparison, this one being made a week after the first.

		Northwestern.	Counted	M. Var.	Counted.
Shenandoah,	July 22,	58.5	1500	67.5	1000
Des Moines,	July 23,	75.9	1000	75.2	1000
Charles City,	July 24,	81.8	500	78.5	1000
Charles City,	July 31,	83.1	1000	78.7	1000

The count on the Northwestern trees at Shenandoah is exceptionally low. It was made in a rather isolated block, although just what is the cause for the smaller average is not clear. It seems probable, from the data obtained in these counts, that the development in southern Iowa is fully ten days ahead of that in northern Iowa, notwithstanding that the nymphs hatched out from the winter eggs at about the same time. The following table, intended to express the periods of greatest abundance of young nymphs, is constructed from the first.

July. 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31.

Shenandoah.....58.5 (Northwestern)
....67.5...(Mixed varieties)
Des Moines ....75.9.....(Northwestern)
.....75.2.....(Mixed varieties)
Charles City (Northwestern) 81.8.. .....83.1
(Mixed varieties 78.5..... 78.7

It appears that the young hoppers were most abundant at Charles City at a time when they were becoming less abundant at Des Moines and Shenandoah. Allowing for some error in the counts, it seems probable that dates five days apart for the southern, central, and northern portions of the state would strike the periods of abundance of the young nymphs. July 20, would seem to be the proper date for Shenandoah, while the 25th and 30th would probably strike the latter part of the abundance at Des Moines and Charles City. These dates, then, show the critical time for the dipping of nursery stock in July.

The same dates would most probably be correct for the month of June, but since the August generation is more scattered than the others, they would be less reliable for that month.

It was found in these counts that there would frequently be much difference between blocks of apple stock, as regards

the state of development of the hoppers. Adjoining blocks of stock differing in size or in varieties showed averages varying as much as 10 per cent in large counts. The leaf-hoppers seemed to develop faster on certain blocks or on certain varieties.

HIBERNATION OF ADULTS.

Doctor Forbes* has said that the species hibernates in the adult stage, but later Forbes and Hart** remarked that "None of the imagoes are recorded in Illinois from November 1st to the last of April, and it is almost certain that they pass the winter in the egg." The former record seems to have been overlooked. Prof. Gillette also recorded the species as hibernating in the adult stage. H. A. Surface recorded adults at Champaign, Illinois, on May 7, 1894. Prof. Garman has remarked that the adults hibernate in Kentucky. The writer has found young nymphs hatching from eggs in early spring in Minnesota. In Iowa, hibernating adults have been found at Shenandoah late in April, (1908) and May, 1909, and also at Ames in June, (1909). No data regarding the hibernation of adults in northern Iowa is available, except that no adults could be found at Charles City May 21-22, 1909. The species winters over in the egg stage on apple trees in all parts of the state.

THE WINTER EGG.

The winter egg of the apple leaf-hopper was first seen May 25, 1907, at Albert Lea, Minnesota, by the writer.*** Somewhat similar eggs had been found by Prof. Geo. G. Ainslie before that time, but these were larger than the eggs of *Empoasca mali,* and probably were the eggs of some Membracid.† The eggs of the apple leaf-hopper were found on 3-year-old apple trees in the nursery row, on the lower parts of the tree. Apple wood at least two years old seems to be the favorite place for the adults to deposit their eggs, although eggs have been found rarely in wood but one year old.

The winter eggs have been found on older apple trees as high as 17 feet from the ground in Minnesota, and in Iowa young nymphs from these eggs have been found 15 feet from the ground.

*Forbes, S. A.-Ento. Amer. Vol. III. p. 174.
**Forbes, S. A. and Hart, C. A.-Ill. Agr. Exp. Sta. Bul. 60. p. 427.
***Washburn, F. L.-Journ. Econ. Ent. Vol. I. p. 143.
†Webster, R. L.-Journ. Econ. Ent. Vol. I. p. 326.

In Iowa these winter eggs have been found as early as September 10. (Webster City, 1909.) They are probably deposited from this time until well into October.

So far as known the winter eggs are placed only in the bark of apple trees. Doctor Franklin has found similar eggs in elm bark in Minnesota, but which were not determined certainly to be those of the apple leaf-hopper. In Iowa similar Jassid eggs have been found in the bark of other nursery trees, but these turned out to be other species; *Empoasca obtusa* Walsh having been bred from willow and poplar and *Typhlocyba rosae* Linn., from elm and maple.

The presence of the egg in the bark is made known from the exterior by a small pouch or blister on the surface. The egg itself is placed just below the epidermis. The pouch is of the same color as the surface of the bark, and unless one knows just what he is looking for, he is not likely to see the pouches at once where they are fairly common. They vary considerable in shape, some are cylindrical, others broader, and still others slightly crescentic in outline. At one end may be found the tiny slit made by the ovipositor of the leaf-hopper when the egg was placed in the bark. The pouch measures about .72 mm long by .21 mm broad, (average of 20 specimens). Several of these egg pouches in the bark are shown much enlarged in figure 7.

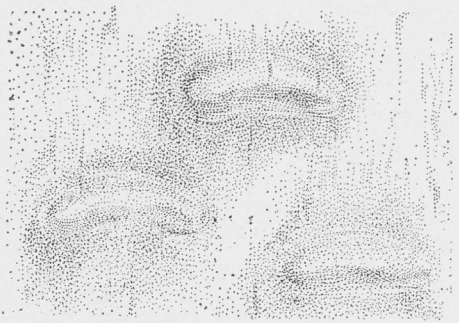

FIGURE 7. WINTER EGG POUCHES IN BARK. ENLARGED 30 TIMES.

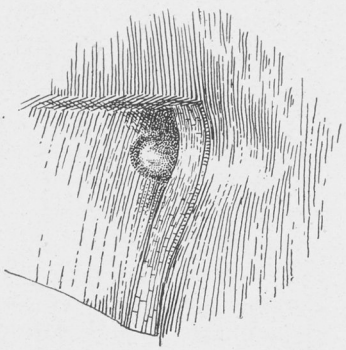

FIGURE 8. WINTER EGG POUCH WITH EGG EXPOSED. ENLARGED 30 TIMES.

The egg itself is elongate, white and delicate, slightly curved in at the middle portion. It is slightly smaller than the pouch in the bark, measuring .63 mm. by .18 mm. The egg is shown in figure 8, where it is partly exposed from the surrounding bark.

THE SUMMER EGG.

During the summer the eggs are deposited in a large number of food plants, in the petiole or in the larger veins of the leaves. This had been suspected by a number of writers and in 1908 nymphs were found in the act of emerging from leaf petioles. This fact was observed in Minnesota and in Iowa on apple leaves.** On June 9, 1909, the writer cut through sections of apple leaves and found the eggs embedded there. The eggs were placed immediately under the surface of the petiole, lying longitudinally. with the curved ends outward. These eggs appeared the same as those found in the apple bark.

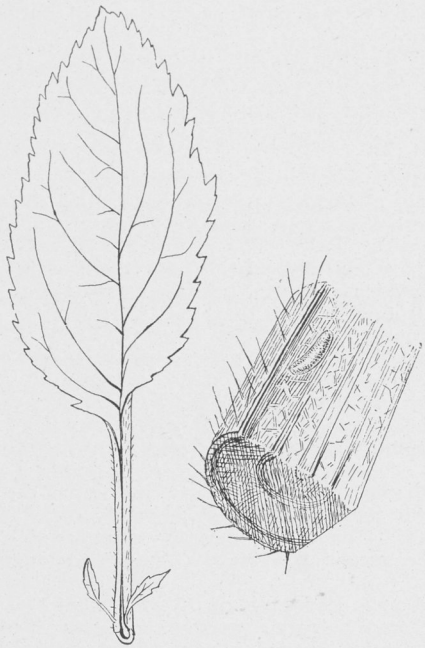

FIGURE 9. SUMMER EGG IN PETIOLE OF APPLE LEAF. LEAF NATURAL SIZE, SECTION MUCH ENLARGED.

No very accurate data has been obtained for the length of the egg stage. An apple twig was placed in an insectary cage August 26, and young nymphs hatched out on September 1, six days later. No adults had been in the cage. In this case then, the egg stage was not less than six days, although it might have been longer than that time.

*Washburn, F. L.-Minn. Agr. Exp. Sta. Bul. 112. p. 152.
**Webster, R. L.-Journ. Econ. Ent. Vol. I. p. 326.

THE NYMPHAL STAGES.

Following is given descriptions of the five nymphal stages, together with average lengths in millimeters. It was noticed that the length of a nymph would often increase from day to day, although it had not molted in the meantime. The measurements given were taken from specimens captured on apple trees and the figures obtained could be grouped easily according to the different stages.

Stage I.

Length I. mm. (Average of 10 specimens.)
Head, thorax, abdomen, and legs pale when first born. After the young hopper has taken some food into the body, the abdomen takes on a yellow color. The eyes are dull reddish. Two rows of six spines are on either side of the meson; one dorso-laterad, one ventro-laterad, in position; one spine in a row to a segment. Spines small, pale. Caudal border of metathorax blunt in outline.

Stage II.

Length 1.26 mm. (Average of 10 specimens.)
Head, thorax, abdomen, and legs pale green; eyes dull reddish. Antenna, segments I and II pale, remainder dusky, Caudal border of metathorax sharp in outline.

Stage III.

Length 1.56 mm. (Average of 10 specimens.)
General color pale yellow, orange on dorsum of abdomen. Eyes dull reddish. The wingpads now appear quite distinctly and reach to the caudal border of the first abdominal segment.

Stage IV.

Length 1.86 mm. (Average of 10 specimens.)
Head and thorax pale; abdomen pale yellow; eyes dull brownish. The wingpads now extend to the caudal extremity of the second abdominal segment.

Stage V.

Length 2.26 mm. (Average of 10 specimens.)
This stage is rather broader than IV. Head, thorax, and wingpads pale green; abdomen dull yellow; eyes dull brownish. The wingpads extend nearly to the caudal border of the fourth abdominal segment. Antenna; I and II pale green, remainder dusky.

Insectary records have shown considerable variance in the time lengths of the stages. The first nymphs which hatched out from the bark of apple trees in the insectary took

FIGURE 10. THE FIVE NYMPHAL STAGES. ENLARGED 15 TIMES.

longer periods to mature than nymphs bred during June and July. For instance, two nymphs bred in the insectary in April, took 21 and 22 days from the time of hatching until the last molt when they became mature. In the middle of the summer four nymphs took 11, 12, 17, and 18 days to mature. In the first case the nymph was placed in a cage July 17, when it measured roughly .8 mm. It molted July 18, 21, 24, 25, and 28, when it became mature. In this case but 11 days were taken from the time the egg hatched to the adult stage. Usually the time is longer than this. Averaging all of the data on stage lengths from insectary notes the following figures have been obtained: stage I, 2. 6 days; II, 2. 8; III, 2. 3; IV, 2. 5; V, 3. 5; total 13.7 days.

There has been some discussion as to whether nymphs of leaf-hoppers are able to hop. In the case of the apple leaf-hopper the writer has seen nymphs of stages IV and V many times hop to some little distance. These observations have been made in the field and in the insectary, under a variety of conditions.

A freak first stage leaf-hopper which had a double abdomen was found at Shenandoah in July. The two portions parted directly back of the thorax. The right hand part was normal in size, but the one on the left was slightly shorter, about two thirds as long. In other respects the nymph was quite normal, and walked about easily with its extra load.

THE ADULT.

The adult leaf-hopper is most conspicuous in the nursery where they often rise in clouds to the font of anyone walking down the rows.

It has been stated that this species is strongly attracted to light, and Doctor Berg's name *photophila* rather indicates that such is the case. The writer has found this species at lights, but it was never especially common, and usually but a few among other species of leaf-hoppers.

On August 9, a lantern was exposed in the midst of young apple trees in the nursery row at Ames, which trees were badly infested with leaf-hoppers. This was done between 9:45 and 10:30 p. m. and but a single leaf-hopper was caught in that time. Again on August 17, a light was exposed in the same place between midnight and 1:45 a. m. and but two of the apple leaf-hoppers were caught.

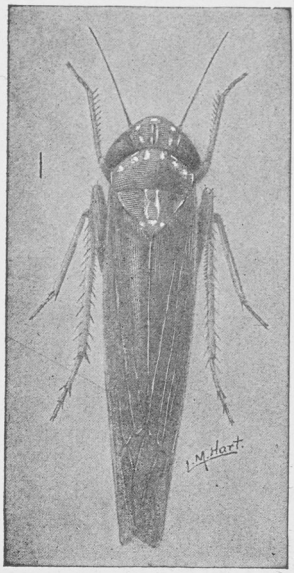

FIGURE 11. THE ADULT LEAF-HOPPER. ENLARGED AS INDICATED. FROM FORBES.

Following is given a description of the adult leaf-hopper.

Yellowish green, usually with white markings, length 3.41 mm. (Average from 20 specimens.)

Face pale green, with a broad white median line; two short diagonal lines at either side, the lower the shorter; two small white spots above the antenna, 2-5 longer than width between eyes, width equal to length of clypeus; clypeus pale green, 1-3 longer than broad; genae pale green, narrow, not attaining the tip of the clypeus, outer margin concave below the eyes; lorae pale green, with one or two white spots, rather long and narrow, almost as long as the clypeus and half as broad. Vertex pale green, with a white median line and a more or less regular white spot caudo-laterad, moderately produced, 1-3 longer at middle than at sides and 2-3 the length of pronotum. Ocelli

two, situated on front margin of vertex and marked by a white spot, distance apart is twice that from the eye to the ocellus; eyes pearl white, brown after death, length equal to that of the pronotum. Pronotum pale green, with a row of six or eight irregular white spots ranged along the cephalic margin, twice as wide as long; scutellum pale green, white stripe laterad along margin, interrupted caudad; long white stripe on either side of meson, connected caudad and sometimes at middle also by a triangular white area. Elytra yellowish green; abdomen greenish, with transverse pale bands which are wider laterad; legs greenish; tarsi pale, dusky at tips.

The description is made from well marked specimens. Frequently the white markings are almost entirely absent.

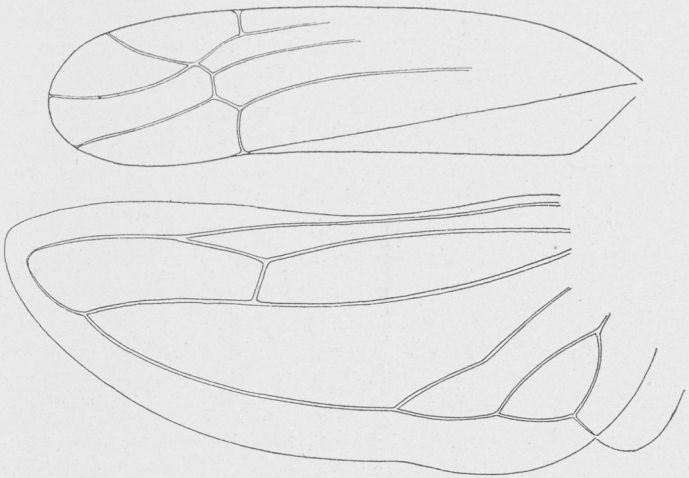

FIGURE 12. WINGS OF ADULT. ENLARGED 32 TIMES.

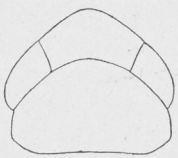

FIGURE 13. OUTLINE OF HEAD FROM DORSUM. MUCH ENLARGED.

NATURAL ENEMIES

Probably the most important enemy of the leaf-hopper is a small black sucking insect which attacks the nymphs, sucking their body juices through tiny beaks. This is *Triphéleps insidiosus* Say, shown much enlarged in figure 14.

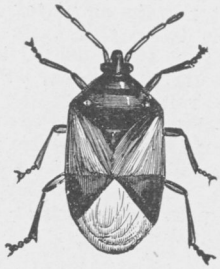

FIGURE 14. TRIPHLEPS INSIDIOSUS, AN ENEMY OF THE LEAF-HOPPER. ENLARGED. AFTER RILEY.

Beginning in July these tiny enemies were found commonly on the curled apple leaves with the leaf-hoppers. Frequently one would be seen with its beak inserted in the soft body of a hopper, which had been caught unawares. These little enemies were common during the summer wherever the hoppers were injurious.

Occasionally larvae of the lace-winged-flies, or Aphis-lions as they are called, attack the hoppers. Larvae have been observed feeding on the leaf-hoppers and *Chrysopa plorabunda* Fitch has been reared from cocoons found on young apple trees badly infested with hoppers.

On June 9, 1909, the writer found a single adult leaf-hopper near Ames which had on its thorax a mite nymph. This mite has been determined for me by Mr. H. E. Ewing as a species of Rhyncholophus, of the family Rhyncholophidæ. Mr. Ewing informs me that the normal habit of the nymphs of this family is parasitic upon soft bodied insects, while the adult mites are plant feeders.

In July, 1908, a small dipterous insect of the family Empidae was found attacking a nymph of *Empoasca mali*. The fly had its tongue inserted in the under side of the nymph's abdomen. There were a number of other flies of the same kind on the adjacent leaves. The insect has been determined for me by Prof. A. L. Melander as an undescribed species of Drapetis, allied to *Drapetis divergens*.

Aside from these enemies, spiders have been observed attacking the leaf-hoppers and feeding on them.

ACKNOWLEDGMENTS.

The writer wishes to acknowledge the many kind suggestions of Professor H. E. Summers during the course of the

work. Professor Herbert Osborn examined a series of *Empoasca mali* and made tentative determinations of *Empoasca obtusa* and *Typhlocyba rosae*. Prof. A. L. Melander, of the State College of Washington, and Mr. H. E. Ewing, of Iowa State College, kindly made determinations of natural enemies of the apple leaf-hopper. Two of the figures of the bulletin were obtained from Doctor S. A. Forbes. The photographs were the work of Mr. F. E. Colburn, and the drawings, unless otherwise indicated, were made by Miss Charlotte M. King. Mr. Henry Ness rendered assistance in the insectary in 1908 and 1909.

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1884 Forbes S. A.—13th Rep. State Ent. III. p. 181. Describes *Empoalbopicta* and records injury to apple stock at Normal, Illinois. Observations made June 26 state that nine tenths of the insects were then in the nymphal stages. On Aug. 6 at Centralia most of the insects were in the adult stage. Uhler stated that the species was new.

1886 Forbes S. A.—Ent. Amer. vol. III. p. 174. Refers to LeBaron's name *mali*. Says that the species hibernates as the adult.

1889 Weed C. M.—Ohio Agr. Exp. Sta. vol. II. no. 6, 2nd series. p. 154. *Typhlocyba albopicta*. Noted on currants and gooseberries. Tobacco dust and pyrethrum effective on the immature stages.

1891 Gillette, C. P.—Trans. Iowa State Hort. Soc. for 1890. p. 104. Injury to apple. Says that the insect hibernates. 2 or 3 percent kerosene emulsion used.

1893 Davis, C. G.—Mich. Agr. Exp. Sta. Bul. 102. p. 28. Injures celery Breeds on plants.

1894 Surface, H. A.—Insect Life Vol. VI. p. 375. *Empoasca mali*. Adults found May 7, 1894 on apple at Champaign, Illinois.

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1900 Forbes, S. A. and Hart, C. A.—Ill. Agr. Exp. Sta. Bul. 60. p. 425. Recorded on sugar beet. Notes on other food plants. Supposed eggs found in apple leaves. Probably four or more broods. Other Jassids which are similar to this species are mentioned. Same article in 21st Rep. State Ent. III. p. 77.

1903 Washburn, F. L.—8th Rep. State Ent. Minn. p. 59. *Empoasca albopicta*. Noted on currants. Dust spraying advised. p. 148. *Empoasca mali*. Reported as injurious to apple stock in

1905 Washburn, F. L.—U. S. Dept. Agr. Bur. Ent. Bul. 60, p. 88. Reports on kero-water spraying; I part kerosene to 15 parts water, partly successful.

1907 Gibson, Arthur—37th. Rep. Ent. Soc. Ont. p. 79. Recorded on basswood at Hull, Quebec, and Brittania-on-the Bay, Ontario. (Metcalfe.)

1908 Garman, H.—Ky. Agr. Exp. Sta. Bul. 133. p. 57. Injury and habits. Adults found up to January 1st.

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1908 Webster. R. L.—Journ. Econ. Ent. vol. I. p. 326. Nymphs observed hatching from petioles of apple leaves in insectary.

1908 Washburn, F. L.—Minn. Agr. Exp. Sta. Bul. 112. p. 145. Says the insect is at least two brooded in Minnesota. Eggs in summer laid in petioles of clover, apple and doubtless many other plants. Notes on life history and food plants: gives list of food plants found in Minnesota. Spraying experiments on apple nursery stock with kerosene emulsion, fish oil soap, tobacco soap solution and resin wash. Account given of use of a sticky shield in nursery stock and of hopperdozer in alfalfa rows. Same article in 12th Rep. State Ent. Minn. p. 11.

1909 Washburn, F. L.—Journ. Econ. Ent. vol. II. p. 54. Fall laid eggs described; similar eggs found on elm; summer eggs; food plants; different stages and number of broods; economic suggestions; refers to trial with sticky shield. Colored plate showing different stages of leaf-hopper .

1909 Shaw, N. E.—Ohio Dept. Agr. Div. Nurs. & Orch. Insp. Rep. Inspector 1908. p. 17. Recorded injury to hollyhocks.

1909 Parrott, P. J.—Journ. Econ. Ent. vol. II. p. 79. Injury to apple, maple, potato and bean. New York.
nurseries. Refers to spraying by Prof. J. M. Stedman in Missouri, and also to an apparatus to be smeared with some kind of "tanglefoot." According to Stedman the kerosene emulsion seems to be effective.

1905 Forbes, S. A.—23rd. Rep. State. Ent. Ill. p. 121. Mentioned on corn. Says probably four or five broods, the first becoming adult in late April or early May. Completes its growth from the egg within a month.

1905 Washburn, F. L.—U. S. Dept. Agr. Bur. Ent. Bul. 52. p. 43. Resistant varieties of apple stock. Spraying with kero-water pump and also with kerosene emulsion. Unsuccessful in killing adults, although the mixtures killed nymphs. Refers to dust spraying at Adrian, Minnesota.